

Spatiotemporal gait parameters in obese and normal-weight pregnant women

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Abstract

Problem statement: Gestational obesity poses a significant strain on the musculoskeletal system of pregnant women, impacting gait patterns, with spatiotemporal gait parameters serving as crucial indicators of these changes. The aim of this study was to assess and compare spatiotemporal gait parameters between obese and normal-weight pregnant women across three distinct gestational periods. **Purpose:** To investigate and contrast spatiotemporal gait parameters in obese and normal-weight pregnant women during three key gestational periods. **Approach:** In this longitudinal study, a cohort of 23 pregnant women was stratified into two groups: a normal-weight group (control group [CG]: n = 12) and an obese group (OG: n = 11). Gait analyses were conducted at three specific gestational periods (T1, 16th week; T2, 24th week; and T3, 32nd week). Utilizing a mixed analysis of variance with three repeated measures, we examined differences and interactions within each period and between the two groups. Effect sizes were determined using generalized eta squared values (η^2). **Results:** Double support time ($p < 0.01$; $\eta^2 = 0.35$), step width ($p < 0.01$, $\eta^2 = 0.37$), and stance phase duration ($p < 0.01$, $\eta^2 = 0.36$) increased from T2 to T3 in both groups and were higher in the OG ($p < 0.01$, $\eta^2 = 0.32$; $p = 0.04$, $\eta^2 = 0.20$; and $p = 0.02$, $\eta^2 = 0.25$, respectively). Step time did not change over the gestational periods. However, the pregnant women in the OG exhibited longer step times than those in the CG ($p = 0.049$, $\eta^2 = 0.20$) at all time points. Cadence, single support time, stride time, and opposite foot contact had no significant differences between the groups and between the gestational periods. Gait speed ($p = 0.01$, $\eta^2 = 0.22$), step length ($p < 0.01$, $\eta^2 = 0.28$), stride length ($p < 0.01$, $\eta^2 = 0.25$), and locomotor rehabilitation index ($p = 0.02$, $\eta^2 = 0.35$) decreased from T1 to T3 in both groups. No interactions were found. **Conclusions:** The pregnant women in this study experienced an elongated double support phase, wider step width, and prolonged stance phase. Gait speed, locomotor rehabilitation index, step length, and stride length were influenced only by pregnancy progression. Step time increased only in the OG.

Keywords: gait, pregnancy, obesity, body mass index, biomechanics

Introduction

Aligned with the global increases in overweight and obesity rates, Brazil is facing a significant public health concern, with approximately 50% of its population classified as overweight or obese (Saúde, 2018). In this context, the prevalence of obesity among pregnant women in Brazil is becoming increasingly pronounced (Rasmussen & Yaktine, 2009). Maternal obesity and excessive gestational weight gain are associated with heightened risks of adverse outcomes in both the mother and the child, such as gestational diabetes and preeclampsia (Rahman et al., 2015).

Furthermore, noticeable changes in spine posture and decreased balance control are observed in pregnant women during the third trimester compared with those in the earlier trimesters of pregnancy and nonpregnant women (Conder et al., 2019). These alterations increase the risk of falls, which are a leading cause of injury in pregnant women. Studies have reported that pregnancy-related falls account for approximately 17% of all injuries requiring hospital admission and are the cause of 21% of all minor injuries (Fischer et al., 2011). In addition, obesity is known to be associated with an increased risk of falls, primarily attributed to its detrimental effects on musculoskeletal system functionality. Obese women may exhibit compromised gait characteristics, including slower walking speed, shorter stride lengths, and reduced sit-to-stand performance and endurance

capabilities (Pataky et al., 2014). In pregnant women, spatiotemporal gait parameters have been recognized as valuable indicators of balance control (Krkelj, 2018), with several authors emphasizing their significance in assessing overall body functionality and health status (Barboza et al., 2021; Ferreira et al., 2023; Peyré-Tartaruga & Passos-Monteiro, 2016; Studenski et al., 2011).

Pregnancy may impact spatiotemporal gait parameters, potentially reflecting biomechanics adaptations. Gait speed, may decrease during pregnancy, suggesting a compensatory mechanism for enhanced safety (Forczek & Staszkiwicz, 2012). Cadence, influenced by pelvic girdle workload, might change due to limitations in mass distribution (Forczek & Staszkiwicz, 2012). Increased inertial load may decrease pelvic amplitude, affecting the double support time (Aguar et al., 2015). Pregnant women may adopt a wider stride for stability (Forczek et al., 2019). Step width increase might result from joint laxity or reflect a stability demand (Aguar et al., 2015; Gilleard, 2013). Single step duration is influenced by dynamic stability improvement (Aguar et al., 2015; Carpes et al., 2008). Stance phase may increase across trimesters, suggesting dynamic adaptation to biomechanical demands during pregnancy (Aguar et al., 2015; Carpes et al., 2008). However, the observed changes in these parameters are not universally consistent across studies (Branco et al., 2016; Krkelj, 2018; Sousa et al., 2018). It is hypothesized that these alterations occur, in general, as a protective mechanism to enhance safety, minimize joint stress, and alleviate discomfort and pain during gait (Riley et al., 2007).

Overweight exacerbates these effects and increases the need for balance control on spatiotemporal gait parameters during pregnancy (Pauk et al., 2020). This adjustment may aid in maintaining the dynamic stability of overweight pregnant women during locomotion.

The observed differences in gait changes likely represent adaptive behaviors in response to unstable postural control (Ferreira et al., 2023). Individuals with obesity tend to expand their base of support for a greater duration within a single gait cycle (Desrochers et al., 2021; Kamarudin et al., 2021). Considering the inherent challenges in gait and balance associated with obesity, it is crucial to assess the severity of gait difficulties and stability in this population to obtain a comprehensive understanding of their movement quality. However, limited studies have focused on evaluating pregnant women with obesity, as opposed to those with overweight.

Consequently, a better understanding of the impact of obesity on spatiotemporal gait parameters during pregnancy is crucial for tailoring specific health-care interventions such as exercise prescriptions. Walking, as a common and popular choice of prenatal physical activity, holds potential as an effective strategy for mitigating gestational weight gain and maternal obesity (Ruchat et al., 2018).

Therefore, the primary objective of this study was to compare spatiotemporal gait parameters between obese and normal-weight pregnant women at different gestational stages. We hypothesized that compared with normal-weight pregnant women, obese pregnant women would exhibit slower gait speed and wider gait step width as adaptive strategies to ensure safety during locomotion.

Materials and Methods

Study sample and design

Pregnant women were recruited from the Obstetrics and Gynecology Service (OGS) of the General Hospital of the University of Caxias do Sul for this observational longitudinal cohort study. A total of 31 pregnant women initially agreed to participate, of whom 16 were classified as obese (obese group [OG]) and 15 were classified as normal-weight (control group [CG]).

The initial sample size of this study was determined using the G*Power software (version 3.1.9.2; Universität Fiel, Germany) (Faul et al., 2007, 2009). In the sample size calculation, a two-group design with repeated measures was considered, with the F-test family, an effect size of 0.25 for gait speed, an alpha error probability of 0.05, and a statistical power of 0.8. On the basis of these parameters, a sample size of 28 individuals was determined.

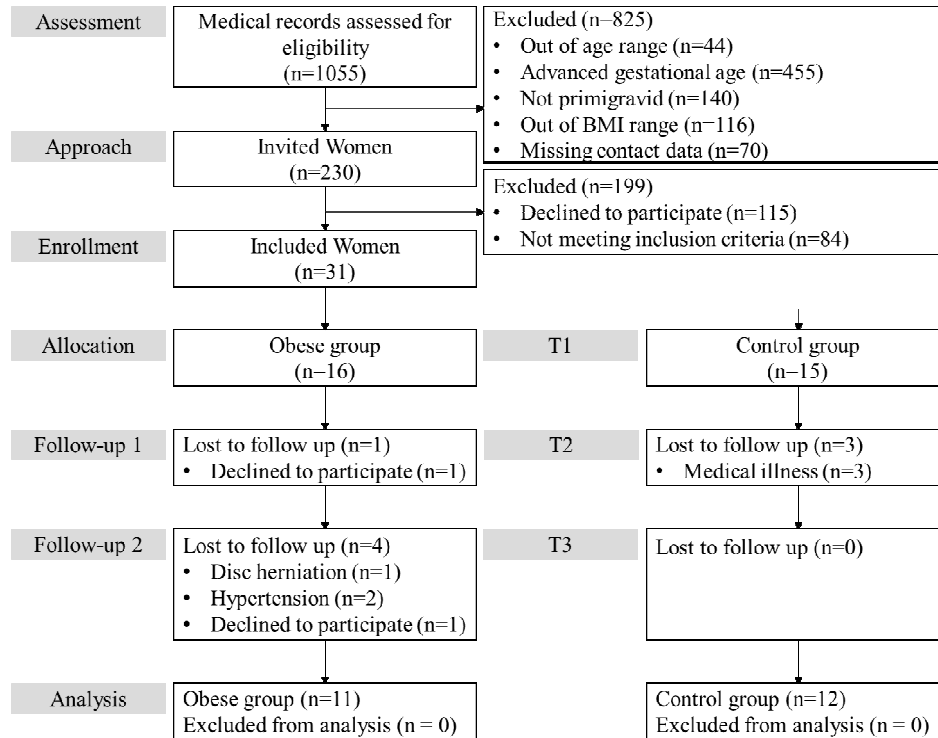
However, during the course of the study, eight participants were lost to follow-up due to dropout or medical reasons (Figure I). Consequently, the final sample size consisted of only 23 pregnant women, with 11 in the OG and 12 in the CG. We acknowledge that this significant sample loss might have impacted the study results; therefore, the effect size and observed power will be discussed accordingly.

The inclusion criteria for this study were as follows: for the OG, a pre-gestational body mass index (BMI) $\geq 30 \text{ kg/m}^2$, and for the CG, a pre-gestational BMI $\geq 18.5 \text{ kg/m}^2$ but $< 24.9 \text{ kg/m}^2$.

The participants were between 18 and 40 years of age and in the first trimester of pregnancy. The exclusion criteria included inadequate glycemic control (ADA, 2021), hypertension (Mehta et al., 2020), and medical history related to recent orthopedic injuries or neurological illnesses such as vestibulopathy.

The study was conducted at the Clinical Center's Gait Laboratory of the Universidade de Caxias do Sul (CECLIN/UCS) from 2018 to 2020. Ethical approval was obtained from the ethics committee of the University of Caxias do Sul (3.028.567) in accordance with the ethical principles outlined in the Declaration of Helsinki.

Figure I: CONSORT flow diagram describing the trial attrition in each stage.



Procedures

Three experimental sessions were conducted at the early (T1: 16 ± 2 gestational weeks), middle (T2: 24 ± 2 gestational weeks), and late gestational periods (T3: 32 ± 2 gestational weeks). The selection of these specific time points was based on practical considerations and the aim of capturing the key pregnancy stages while also ensuring equal time intervals between T1 and T2, and between T2 and T3. The information on gestational age was obtained from the participants' medical records, which were carefully documented by their obstetricians and gynecologists from the OGS using the established and validated methods commonly used in obstetric practice for accurate determination of gestational age in weeks (Fung et al., 2020).

During the experimental sessions conducted at three different gestational age intervals, we collected standard anthropometric measurements, including stature, body mass, and BMI. In addition, we assessed limb parameters relevant to the gait model, such as leg length (measured using a measuring tape from the anterosuperior iliac spine to the lower edge of the malleolus), knee width (intercondylar distance), and ankle width (intermalleolar distance measured using an osteometer). Blood pressure readings were also obtained. Prior to these measurements, the participants were requested to complete a questionnaire that elicited information regarding their gestational ages, medication usage, and general health.

Subsequently, the participants were instructed to walk along a 12-m walkway twice for familiarization, without shoes and wearing appropriately fitting clothing or shorts, while maintaining a comfortable walking speed consistent with their daily routine. All volunteers were given the following instructions: "Walk comfortably at a speed that feels most natural and similar to your everyday pace along the path in front of you, going back and forth, without the need to stop. We will ask you to stop once we have collected the appropriate number of steps. At any time, you may request to stop the trial or take a rest." Data collection was conducted until at least the results of 10 trials were adequately recorded for each participant, ensuring at least five steps with the left leg and with the right leg on the force plate.

Data collection and analysis

The spatiotemporal gait parameters were recorded using the optoelectronic motion capture system of seven integrated infrared cameras (Vicon MX Systems, Oxford Metrics Group, UK) operating at a sampling frequency of 100 Hz synchronized with an AMTI force plate (OR6-7, Advanced Mechanical Technologies, MA). Eighteen reflective markers were strategically placed on the subject's body following the Vicon Plug-in Gait model setup (Kainz et al., 2017; Riley et al., 2007; Stief et al., 2013). The computed dependent variables included gait speed (m/s), cadence (steps/min), double support time (s), single support time (s), step length (m), step width (m), step time (s), stride length (m), stride time (s), stance phase duration (expressed as a percentage of the gait cycle), and opposite foot contact (expressed as a percentage of the gait cycle).

In addition, we evaluated the locomotor rehabilitation index (LRI; equation 1) as a marker of mechanical and metabolic performance to provide complementary insights into the analysis of spatiotemporal parameters

and valuable information about locomotor function (Barboza et al., 2021; Peyré-Tartaruga & Passos-Monteiro, 2016).

$$LRI = \frac{100 \times \text{gait speed}}{\sqrt{0.25 \times 9.81 \times \text{leg length}}} \quad (\text{Equation 1})$$

Statistical analysis

The aim of the present study was to compare the dependent variables across three gestational periods (three repeated measures: T1 vs. T2 vs. T3) and between two independent groups (CG vs. OG). After verifying and confirming the assumptions of normality (Shapiro-Wilk test) and sphericity (Mauchly test), a mixed design analysis of variance (ANOVA; 3 × 2 mixed ANOVA) was performed to identify intra-period and inter-group effects (Field, 2013). When significant main effects or interactions were found, a *post hoc* test with Bonferroni correction was used to further examine for significant effects. We computed the results of the ANOVA *p* value, ANOVA *F* statistic index, and 1-β observed statistical power (SP) for each dependent variable analysis. Effect sizes were determined on the basis of generalized eta squared (η^2) values for the ANOVA as follows: 0.020–0.129 as small (S), 0.130–0.259 as medium (M), and >0.26 as large (L) (Bakeman, 2005; Cohen, 1988). Statistical analyses were performed using the IBM Statistical Package for Social Science software (version 23.0; SPSS Inc., Chicago, IL), with an alpha of 0.05.

Results

A total of 23 pregnant women (11 in the OG and 12 in the CG) were included and evaluated in this study (Table I). The spatiotemporal gait parameters showed no significant differences in age, gestational age, parity, number of previous abortions, and stature between the groups (Table I).

Table I: Characteristics of the pregnant women in the obese and control groups over the three gestational periods (T1, T2, and T3)

Variables	CG	OG	<i>P</i> -value
Age (years)	28 ± 7	29 ± 5	0.953
Gestational age (weeks)			
T1	16.0 ± 1.8	15.4 ± 2.1	0.490
T2	24.3 ± 2.1	23.4 ± 1.7	0.306
T3	32.9 ± 2.2	32.4 ± 2.3	0.681
Births > 1*	2	3	0.400
Abortion*	2	1	0.521
Stature (m)	1.63 ± 0.06	1.63 ± 0.08	0.926
Body Mass (kg)			
T1	58.2 ± 7.9	94.2 ± 15.5	< 0.001
T2	65.4 ± 9.3	96 ± 17.1	< 0.001
T3	70 ± 9.5	100.5 ± 18.4	< 0.001
BMI (kg/m ²)			
T1	22.2 ± 2.00	35.3 ± 4.9	< 0.001
T2	24.8 ± 2.8	36.5 ± 5.4	< 0.001
T3	26.4 ± 2.57	37.7 ± 6.1	< 0.001

The results are presented as mean ± standard deviation. *Absolute numbers. BMI: body mass index. T1, T2, and T3: time points 1, 2, and 3, respectively. CG: control group. OG: obese group

No significant differences in main effects on cadence, single support time, stride time, and opposite foot contact were found between the groups and across the gestational periods. In addition, no significant interactions between time points and groups were found in any spatiotemporal gait parameters. These findings indicate that the two groups had no notable differences in spatiotemporal gait parameters at the different gestational periods, as summarized in the last row of Table II.

Double support time ($F_{(1,17)} = 8.76$, $p < 0.01$, $1-\beta = 0.80$, $\eta^2 = 0.32$ [L]), step width ($F_{(1,17)} = 4.84$, $p = 0.04$, $1-\beta = 0.55$, $\eta^2 = 0.20$ [M]), and stance phase duration ($F_{(3,17)} = 6.45$, $p = 0.02$, $1-\beta = 0.68$, $\eta^2 = 0.25$ [M]) were consistently higher in the OG than in the CG. These parameters also showed significant increases from T2 to T3 ($F_{(2,17)} = 10.33$, $p < 0.01$, $1-\beta = 0.98$, $\eta^2 = 0.35$ [L]; $F_{(2,17)} = 11.02$, $p < 0.01$, $1-\beta = 0.99$, $\eta^2 = 0.37$ [L]; and $F_{(2,17)} = 10.89$, $p < 0.01$, $1-\beta = 0.99$, $\eta^2 = 0.36$ [L], respectively).

Step time remained unchanged throughout pregnancy (all gestational periods) but was longer in the OG than in the CG ($F_{(1,17)} = 4.40$, $p = 0.049$, $1-\beta = 0.51$, $\eta^2 = 0.20$ [M]). Gait speed ($F_{(2,17)} = 5.24$, $p = 0.01$, $1-\beta = 0.80$, $\eta^2 = 0.22$ [M]), step length ($F_{(2,17)} = 7.39$, $p < 0.01$, $1-\beta = 0.92$, $\eta^2 = 0.28$ [M]), stride length ($F_{(2,17)} = 6.31$, $p < 0.01$, $1-\beta = 0.88$, $\eta^2 = 0.25$ [M]), and LRI decreased ($F_{(2,17)} = 5.00$, $p = 0.02$, $1-\beta = 0.74$, $\eta^2 = 0.35$ [L]) from T1 to T3 (Table II). Only double support time reached statistical power and a large effect size. However, this result must be interpreted with caution after statistical power and effect size measures have been considered individually within the study variables (Baguley, 2004).

Table II. Values of the spatiotemporal gait parameters for the OG and CG at the three gestational periods (T1, T2, and T3)

	CG			OG			ME	of ME	Interactions	vs.
	T1	T2	T3	T1	T2	T3	Gestational Times (T1 vs. T2 vs. T3)	Group (CG vs. OG)	of between factors (Time Group)	
							Sig - ES (F; η^2 ; 1- β)	Sig - ES (F; η^2 ; 1- β)	Sig - ES (F; η^2 ; 1- β)	
Speed (m/s)	1.25 ± 0.12	1.19 ± 0.12	1.17 ± 0.10	1.16 ± 0.11	1.18 ± 0.10	1.14 ± 0.08	0.01* M (5.24; 0.22; 0.80)	0.28 (1.22; 0.06; 0.18)	0.11 (2.39; 0.45)	0.11;
Cadence (steps/min)	114.5 ± 6.1	112.2 ± 6.6	112.2 ± 5.1	110.2 ± 6.2	110.3 ± 6.0	108.9 ± 4.6	0.16 (1.94; 0.09; 0.38)	0.07 (3.60; 0.16; 0.44)	0.15 (1.97; 0.38)	0.09;
Double support time (s)	0.19 ± 0.04	0.21 ± 0.03	0.23 ± 0.02	0.24 ± 0.03	0.24 ± 0.03	0.25 ± 0.03	<0.01* L (10.33; 0.98) T1 = T2 < T3	0.35; (8.76; 0.32; 0.80) OG > CG	0.11 (2.32; 0.44)	0.11;
Single support time (s)	0.43 ± 0.02	0.43 ± 0.02	0.42 ± 0.02	0.43 ± 0.03	0.43 ± 0.02	0.43 ± 0.02	0.05 (3.19; 0.14; 0.58)	0.48 (0.53; 0.03; 0.11)	0.71 (0.35; 0.10)	0.02;
Step length (m)	0.65 ± 0.05	0.63 ± 0.04	0.63 ± 0.04	0.63 ± 0.05	0.64 ± 0.05	0.63 ± 0.05	<0.01* L (7.39; 0.28; 0.92) T2 = T1 > T3 = T2	0.82 (0.05; <0.01; 0.06)	0.36 (1.07; 0.22)	0.05;
Step width (m)	0.14 ± 0.03	0.15 ± 0.03	0.17 ± 0.03	0.18 ± 0.03	0.18 ± 0.04	0.19 ± 0.04	<0.01* L (11.02; 0.99) T1 = T2 < T3	0.37; (4.84; 0.20; 0.55) OG > CG	0.24 (1.48; 0.30)	0.07;
Step time (s)	0.52 ± 0.03	0.54 ± 0.03	0.54 ± 0.03	0.55 ± 0.03	0.55 ± 0.03	0.55 ± 0.02	0.10 (2.42; 0.11; 0.46)	0.049* M (4.40; 0.20; 0.51) OG > CG	0.06 (2.96; 0.54)	0.13;
Stride length (m)	1.31 ± 0.09	1.27 ± 0.08	1.25 ± 0.08	1.26 ± 0.10	1.27 ± 0.10	1.26 ± 0.10	<0.01* M (6.31; 0.25; 0.88) T2 = T1 > T3 = T2	0.94 (0.01; 0.05)	0.22 (1.59; 0.32)	0.08;
Stride time (s)	1.05 ± 0.06	1.07 ± 0.07	1.07 ± 0.05	1.09 ± 0.06	1.09 ± 0.06	1.11 ± 0.05	0.14 (2.07; 0.10; 0.40)	0.06 (4.08; 0.18; 0.48)	0.12 (2.28; 0.44)	0.11;
Stance duration (% cycle)	58.9 ± 1.26	59.8 ± 0.84	60.9 ± 0.92	60.9 ± 1.42	60.9 ± 1.34	61.5 ± 1.42	<0.001* L (10.89; 0.99) T1 = T2 < T3	0.36; (6.45; 0.25; 0.68) OG > CG	0.07 (2.79; 0.52)	0.13;
Opposite contact (% cycle)	49.94 ± 0.23	49.9 ± 0.17	49.95 ± 0.10	49.95 ± 0.15	49.99 ± 0.18	49.91 ± 0.10	0.75 (0.29; 0.02; 0.09)	0.87 (0.03; <0.01; 0.05)	0.16 (1.94; 0.38)	0.09;
Locomotor Rehabilitation Index (%OWS)	1.01 ± 0.02	0.96 ± 0.03	0.95 ± 0.02	0.94 ± 0.02	0.95 ± 0.03	0.91 ± 0.02	0.02* L (5.00; 0.35; 0.74) T2 = T1 > T3 = T2	0.14 (2.28; 0.11; 0.30)	0.10 (2.41; 0.45)	0.11;

The results are presented as mean $\pm$ standard deviation. ME: main effect. Sig: p value found in the mixed ANOVA test for the main effects and interaction. F: ANOVA F statistics ratio. 1- β : observed statistical power. η^2 : effect size. ES: effect size classification (S: small η^2 [0.020–0.129]; M: medium η^2 [0.130–0.259]; L: large η^2 [>0.26]). %OWS: percentage of optimal walking speed. Significant comparisons are highlighted in bold with an asterisk (*). *Post hoc* results with Bonferroni correction are summarized below each significant main effect.

Discussion

Maternal body mass index is linked to unfavorable health outcomes both for the child and the mother (Rahman et al., 2015). Our main goal was to compare spatiotemporal gait parameters between obese and normal-weight pregnant women over three gestational periods, as these parameters are considered good health indicators (Barboza et al., 2021; Krkeljas, 2018; Studenski et al., 2011). Previous studies have primarily examined the effects of pregnancy on gait parameters, with a limited focus on obese pregnant women. Consequently, our study fills a significant gap in the scientific literature by being the first to assess the gait characteristics of both obese and normal-weight pregnant women.

The pregnant women in the OG presented a 19% wider step width and 2% longer stance phase duration than those in the CG. The differences in the two parameters between the groups were both significant (Geiger et al., 2019; Soulard et al., 2021). Obese women may need to increase their base of support and spend more time in contact with the ground during walking, probably to compensate for deteriorations in the sensory integration mechanisms and proprioceptive capacities associated with weight gain and relaxin levels, which can impact the quality and quantity of the sensory information provided by the joints and plantar mechanoreceptors while maintaining balance during gait (Wu & Madigan, 2014).

Clinically relevant effects (Souillard et al., 2021) of obesity (15% longer) and gestational periods (16% longer) on double support time were observed. Prolonged double support is frequently linked to a safer balance strategy in overweight pregnant women (Pauk et al., 2020). Consequently, for women with a double support time, clinicians should apply appropriate strategies and interventions to enhance balance (Morris et al., 2017). The step time was 0.016 s longer in the OG than in the CG, indicating a slight increase in the duration of each step. Although this difference was statistically significant and had a medium effect size, it should be interpreted with caution in clinical settings, as differences of at least 0.03 s are considered clinically relevant according to previous studies (Washabaugh et al., 2017). Therefore, our finding may not be deemed clinically meaningful in practical applications. We hypothesized that these differences, albeit small, occur to maintain better balance (Hak et al., 2012). Individuals with slower step times may benefit from exercises targeted at improving balance control.

The literature on the effect of gestational age on spatiotemporal gait parameters presents highly conflicting findings. Pauk et al. (Pauk et al., 2020) reported longer double support times in the third trimester, whereas Krkeljas (Krkeljas, 2018) and Branco et al. (Branco et al., 2016) did not find differences between trimesters. Step width was wider according to Forczek et al. (Forczek et al., 2019) and Gilleard (Gilleard, 2013), but Krkeljas (Krkeljas, 2018) and Branco et al. (Branco et al., 2016) did not observe such differences. Similarly, Carpes et al. (Carpes et al., 2008) found a longer stance phase, whereas Pauk et al. (Pauk et al., 2020) did not. Moreover, in the present study, pregnant women (in the CG and OG) exhibited a 1.5% slower cadence at T3, which contradicts the findings of previous studies (Forczek et al., 2019). However, none of these studies included obese women in their samples. For example, the study of Pauk et al. (Pauk et al., 2020) only included overweight women. This lack of consistency among studies underscores the necessity for a systematic review and meta-analysis to comprehensively evaluate these variables in pregnant women.

To the best of our knowledge, this is the first study to observe a decrease in gait speed (4% or 0.05 m/s slower in T3) between the gestational periods (Branco et al., 2016; Forczek et al., 2019; Gilleard, 2013; Krkeljas, 2018; Pauk et al., 2020; Sousa et al., 2018). The relevance of gait speed in clinical practice is gaining recognition. For instance, in elderly individuals, speed can be an indicator of survival and life expectancy (Studenski et al., 2011). However, these measures do not seem to be directly linked to balance control (Hak et al., 2012). It is well known that pregnant women tend to walk at a slower pace than nonpregnant women (Forczek & Staszkiwicz, 2012), and the added weight during pregnancy contributes to changes in gait speed (Aguir et al., 2015). Moreover, in the later stages of pregnancy, the fear of falling prompts women to adopt a slower walking speed (Gilleard, 2013). In our study, it is important to discuss the clinical relevance of the small difference observed between T1 and T3. Generally, clinically relevant differences typically range from 0.1 to 0.2 m/s (Bohannon & Glenney, 2014) or from 10% to 17% (Geiger et al., 2019; Soulard et al., 2021), and 0.05 m/s is below this range. However, clinicians should be attentive to pregnant women who walk at speeds < 1 m/s (T3 average minus 2 standard deviations) to understand whether this is associated with their overall health or fear of falling and to provide specific clinical interventions addressing these issues.

Furthermore, we observed a lower LRI in the third trimester than in the first trimester, with no significant effects of obesity on this variable. The LRI represents the relationship between self-selected walking speed, a mechanical marker of walking, and optimal walking speed, a metabolic marker of walking, providing complementary insights into gait assessment (Barboza et al., 2021). When the self-selected and optimal walking speeds align, walking is considered functional and healthy (Peyré-Tartaruga & Passos-Monteiro, 2016). The LRI has been recognized as an important performance marker with clinical relevance. We speculate that the physiological changes that occur in women during the later stages of pregnancy may affect their motor performance, leading to a reduction in LRI values.

For practical recommendations, while we acknowledge that further assessment and validation of exercise prescriptions are necessary, we tentatively recommend the inclusion of exercises targeted at improving balance, stability, and energy expenditure for obese pregnant women exhibiting the identified alterations in gait mechanics (Morris et al., 2017; Ruchat et al., 2018). However, we recognize the speculative nature of these suggestions and acknowledge that more comprehensive studies are required to establish the effectiveness and safety of such exercise prescriptions.

Some limitations of this study must be acknowledged. In this study, gestational period T1 did not start at the very beginning of pregnancy because of the lack of patients in the early stage of pregnancy in our local health service. However, other studies have markedly varied in the weeks evaluated during each gestational period, making a comparison difficult (Forczek et al., 2019; Gilleard, 2013; Krkeljas, 2018; Pauk et al., 2020).

Owing to complications during the research or to the specificity of our sample, we obtained a relatively small sample size. However, with the large effect sizes and observed statistical powers in the significant comparisons in our study, we believe that our results can be used as a reference by clinicians of movement rehabilitation and gait treatment. Moreover, we did not impose specific walking speeds on the participants. This decision was a deliberate trade-off, as our objective was to capture the participants' comfortable and natural walking patterns during pregnancy.

Conclusion

Our study results demonstrate that the obese pregnant women assessed in this study experienced an elongated double support phase, a wider step width, and a prolonged stance phase duration. However, gait speed, LRI, step length, and stride length were predominantly influenced by the progression of pregnancy and remained unaffected by obesity. These findings underscore the importance of considering both pregnancy and obesity as factors impacting gait, with specific attention to double support time as a clinically relevant parameter in practice, which was the only parameter that showed a significant difference with a large effect size and high statistical power in the two main effects evaluated (group and time). This understanding is also pivotal for developing interventions and rehabilitation strategies targeted in controlling the stance phase, step width, step time and stance phase duration.

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